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CHARACTERISTICS OF ROCK GRENADIER ACCUMULATIONS AND ITS BEHAVIOURAL RESPONSE TO TRAWLS

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In this work we examine the characteristics of stocks of the rock grenadier /122 Macrurus (coryphaenoides) rupestris (G.) in the region of the Middle Atlantic Ridge (MAR), its behavior with respect to trawls and trawl design parameters suitable for fishing in this region. The studies were done on voyages of the "Gangut" BMRT (large freezer fisheries trawler) and "Sadko" and "Asteroid" RTM-A (freezer fisheries trawlers).

Characteristics of rock grenadier stocks. The characteristics of the distribution and habitat of the fishes were studied using the "Priboi 101" and KhAG-402 on-board hydroacoustic devices. Rock grenadier accumulations were registered on the self-recorders of thedevices in the form of echo-dispersing "fields", consisting of large forms of plankton and shoals of fishes. On underwater elevations at depths of up to 600 m, the fish accumulations are usually situated /123 below the mountain top, as though shrouding its slopes in the 700-1500 m layer.

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*The numbers in the right-hand margin indicate the corresponding pages in the original. - Transl.

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Over banks with depths of more than 600 m, the rock grenadier lingers above the peak and on the slopes to depths of 1500 m. This distribution is apparently due to the fact that the fish keeps strictly to a definite isotherm.

Echo-dispersing fields on many fisheries banks have a vertical development of 30 to 140 m and a horizontal length of 500 to 3500 m. The lower boundaries of these echo-dispersing fields in some cases are elevated above the bottom by 60-70 m, and in others touch the peaks or the mountain slope.

The rock grenadier accumulations change the level of their habitation depending on the time of day: they rise somewhat upslope at night and descend in the day, that is, they are constantly making vertical migrations.

The echo-dispersing fields are not homogeneous in structure; they show local accumulations (spots) with high biomass density. The levels of habitation and the dimensions of local rock grenadier accumulations are shown below.

	Depth of habitation of center of local accumulation, m						
	600-800	800-1000	1000-1200	1200-3600	1600		
Frequency of occurrence %	9.4	36.0	33.4	13.9	7.3		
	Vertical development of local accumulations, m						
	up to 10	10-20	20-30	30-40	40-50	50-60	60
Frequency of occurrence %	1.2	10.3	25.3	33.0	13.3	5.9	11.1
	Horizontal length of local accumulation, m						
	up to 100	100-200	200-300	300-400	400		
Frequency of occurrence %	2.6	9.6	14.6	17.8	55.4		

The most accurate data on the structure of accumulations were obtained by towing the acoustic carrier of the"Igla" deep-water complex in the direct proximity of the accumulation. It was established that the local accumulations of the rock grenadier consist of a multitude of small concentrations with a vertical development of 1-12 m (mainly 4-6 m), a horizontal extent of 2-12 m (most often

4-6 m), and separated from each other by a distance of 20 to 120 m /124
(predominantly 30-60 m). The parameters of the shoals and the distances between them change very little in the course of a day.

On approaching the trawl, evidently under the influence of a complex of stimuli caused by the fishing gear (acoustic and hydrodynamic fields, as well as the bioluminescence of the trawl), the rock grenadier schools compact somewhat. That is, the schools which were at the mouth of the trawl were smaller in vertical development and horizontal extent than the shoals encountered outside the catching zone.

Table 1 presents the averaged dimensions from the weighted-mean distribution and size of rock grenadier schools in the region of the Eureka* banks (1975-1976), located both outside the catching zone as well as at the mouth of a midwater trawl.

TABLE 1

Averaged dimensions from weighted-mean distribution and size of schools.

School parameters	School size	Number of samples
Vertical development	4.39 5.20	693 488
Horizontal extent	7.02 7.80	693 488
Distance between school centers	96.40 128.40	636 424

Note: Dimensions of school (in m) in catching zone above the line, under catching zone under the line.

The investigations showed that the nature of the distribution of rock grenadier schools and their size varies negligibly in different times of the year at a number of commercial banks. Tables 2, 3, and 4 show the frequency of occurrence of schools in the mouth part of the trawl as a function of their

*Spelling approximate.-Transl.

vertical development, horizontal length and the distance between school centers, respectively.

Analysis of the rock grenadier school parameters (see Table 1) shows that the concentrations that were met in 1975 differed little in size from those caught on the same banks in 1980. The consistent nature of the distribution of the rock grenadier in differenttimes of the year is indicative of the stability of the accumulations. Some difference in the /125 intervals between separate schools may perhaps be explained by a change in the rock grenadier catching tactics. While at the start of the development of the deep-water fishery, the trawl was simply towed over the echo-dispersing field, as experience was accumulated, they began to tow the trawl over local areas with high biomass density, as a result of which the frequency of occurrence of schools separated from each other by smaller distances began to increase.

TABLE 2

The frequency of occurrence of schools in the trawl mouth as a function of their vertical development.

Размерный ряд по вертикальному развитию косяков, м (1)	Частота встречаемости косяков макруруса (%) на банках					
	Хекате (3)	Эврика (4)	Майская (5)	Хекате (3)	Эврика (4)	Майская (5)
	Март-апрель 1980 г. (6)			Октябрь-ноябрь 1980 г. (7)		
I-2	I8,5	8,8	9,I	3,0	3,0	I,0
2-4	42,0	28,8	68,I	35,0	42,0	45,0
4-6	26,0	26,6	I3,7	36,0	36,0	32,0
6-8	6,2	I5,5	9,I	I8,0	II,0	I4,0
8-I0	5,5	I7,7	0	5,0	6,0	7,0
I0-I2	I,2	2,6	0	2,0	I,0	I,0
>I2	0,6	0	0	I,0	I,0	0

Key: 1 - school series in terms of vertical development, m; 2 - frequency of occurrence of rock grenadier schools (in %) on banks: 3 - Hecate; 4 -Eureka; 5 - Maiskaya; 6 - March-April, 1980; 7 - October-November, 1980.

TABLE 3

Frequency of occurrence of schools at the trawl mouth depending on their horizontal length.

Размерный ряд по горизонтальной протяженности косяков, м (1)	Частота встречаемости косяков макруруса (%) на банках (2)					
	Хекате (3)	Эврика (4)	Майская (5)	Хекате (3)	Эврика (4)	Майская (5)
	Март-апрель (6) 1980 г.			Октябрь-ноябрь (7) 1980г.		
1-2	16,6	15,5	4,5	2,5	2,0	1,0
2-4	35,9	28,8	77,3	33,5	43,0	50,0
4-6	37,7	42,2	13,7	33,5	33,0	24,0
6-8	7,4	13,5	4,5	21,0	13,0	14,0
8-10	1,2	0	0	5,0	6,0	6,0
10-12	1,2	0	0	4,5	2,0	4,0
>12	0	0	0	0	1,0	1,0

Key: 1 - school series in terms of horizontal length, m; 2 - frequency of occurrence of rock grenadier schools (%) on banks: 3 - Hecate; 4 - Eureka; 5 - Maiskaya; 6 - March-April, 1980; 7 - October-November, 1980.

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TABLE 4

Frequency of occurrence of schools at the trawl mouth as a function of the distance between school centers.

Размерный ряд по расстоянию между косяками, м (1)	Частота встречаемости косяков макруруса (%) на банках (2)					
	Хекате (3)	Эврика (4)	Майская (5)	Хекате (3)	Эврика (4)	Майская (5)
	Март-апрель (6) 1980 г.			Октябрь-ноябрь (7) 1980г.		
<20	66,9	71,6	52,8	2,0	6,5	5,0
20-40	26,0	28,4	33,4	34,0	32,0	32,0
40-60	7,1	0	12,8	22,0	21,0	18,0
60-80	0	0	1,0	19,0	15,5	17,0
80-100	0	0	0	10,0	15,5	12,0
100-120	0	0	0	8,0	4,0	9,0
>120	0	0	0	5,0	5,5	7,0

Key: 1 - series in terms of distance between schools, m; 2 - frequency of occurrence of rock grenadier schools (%) on banks: 3 - Hecate; 4 - Eureka; 5 - Maiskaya; 6 - March-April, 1980; 7 - October-November, 1980.

The experimental data on the characteristics of rock greandier schools /126
encountered in the mouth part of the trawl, obtained on voyages of the "Gangut" BMRT were analysed in order to establish the pattern of the distribution of their frequency of occurrence. It was discovered that on the main fisheries banks, the frequency of occurrence of schools in the catching zone as a function of vertical development corresponds for the most part to log-normal, Maxwell and Rayleigh distribution, while the horizontal length and the distance between schools correspond to log - normal and Maxwell distribution.

Rock grenadier schools that turned up in the mouth part of the trawl showed comparatively low activity. Analysis of the registration on the echo-tapes of the trawl sound shows that only 30-40% of the schools change the level of their initial habitation, going either up or down, while the rest do not change.

Table 5 presents the findings on the direction of departure of rock grenadier schools in the mouth part of a midwater trawl in work at a number of banks in October-November 1980 ("Gangut" BMRT).

Behavior of the rock grenadier in the trawl. The behavior of the rock grenadier in the trawl was studied by means of a double-belly trawl having a single mouth, to which were attached two bellies with trawl codends. One of the bellies was taken as a standard and was not varied in the process of testing; the other belly was taken as experimental. Three versions of the two-belly trawl were tested. In the first variant, the two belly parts were made of net webbing of the same sort. The tests in this variant were done in order to /127
determine the direction of movement of the rock grenadier in the trawl. One might assume that a school of fish that has found itself in the mouth will move either to the left or to the right belly or it will not make a purposeful selection.

TABLE 5

Direction of movement of rock grenadier schools in mouth of trawl.

Банка 1	2 Усредненные данные направления ухода, %		
	не меняют горизонта 3	вверх 4	вниз 5
6 Безымянная	67,2	I3,6	I9,2
7 Добрая	64,0	I7,7	I8,2
8 Восточная	62,7	20,7	I6,6
9 Горбатая	70,6	I0,0	I9,4
10 Майская	62,0	24,0	I4,0
11 Пингвин	66,7	I3,7	I9,6
12 Гекате	57,6	I8,9	23,5
13 Эврика	6I,0	20,0	I8,8
I4 В среднем	64,0	I7,3	I7,7

Key: 1 - banks; 2 - averaged data of direction of movement, %; 3 - do not change level; 4 - up; 5 - down; 6 - Unnamed;** 7 - * Dobraya; 8 - Eastern;*** 9 - Gorbataya; 10 - Maiskaya; 11 - Penguin; 12 - Hecate; 13 - Eureka; 14 - Average.

The second variant differed from the first in that the net webbing region with 800 mm mesh was replaced in the experimental belly by a honeycomb of cables.

The third trawl version differed from the first in that the net webbing with 800 and 400 mm mesh was replaced in the experimental belly with 200 mm net webbing.

In the tests with the second and third variants, the departure of the rock grenadier through net webbing with different mesh size and the cables in the front part of the trawl was studied.

In catching schools of fish above the peak of underwater elevations, the trawl level was established at the center of the denser echo-dispersing layer, registered by the echo sounder; in catching rock grenadier accumulations situated on the slope of banks, the trawler was "landed". Table 6 shows the

*Original Bezymyannaya banka.-Transl. ***Original Vostochnaya banka.-Transl.

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TABLE 6

Results of the tests of the three variants of the 2-belly trawl.

1 Показатели	2 Первый вариант		3 Второй вариант		4 Третий вариант	
5 Шаг ячеи, мм	800 (эталон) 6	800	800 (эталон) 6	Канатное полотно 7	800 (эталон) 6	200
8 Вылов рыбы за время испытания, кг	28I00	28200	24300	I9400	I6800	24600
9 Отношение улова экспериментальной мотни к эталонной, %	I00	I00	I00	80	I00	I46

Key: 1 - indicators; 2 - first variant; 3 - second variant; 4 - third variant; 5 - mesh, mm; 6 - (standard); 7 - cable webbing; 8 - fish caught during test, kg; 9 - ratio of catch with experimental belly to catch with standard belly, %.

results of the tests of these versions of the two-belly trawls. /127

It follows from the findings in Table 6 that the catching qualities of the trawl fall off markedly with increase in mesh size in the trawl belly.

To quantitatively assess the exit of fish, fine-mesh coverings /128 (fish-catchers) were installed in the different sections of the trawl. Analysis of data on fish emergence showed that about 25% of the fish goes out through the belly part with 200 mm mesh, up to 35% with 800 mm mesh, and in the case of cable webbing, more than 60% of the catch in the codend of the corresponding belly part. The most intensive exit of the rock grenadier is observed in the trawl section where the perimeter of the net cone is 60-70 m with a hanging coefficient $u \simeq 0.5$. This may be due to an increase in th concentration of fish in this region of the trawl or to the presence of a "critical zone" such as is observed in trawls in catching fish in epi- and mesopelagic zones. The main

directions of the departure of the rock grenadier through the meshes of the netting were not traced. If the trawl was towed at the same level, without changing course then a uniform emergence of fish was observed at the perimeter in the study trawl sections. But the picture changes drastically if during trawling the couse or the level of trawl towing is changed.

Thus, if trawling is done on a slope from top to bottom, then most of the fish exits through the upper face; when trawling is done along an isobath rounding the apex of the banks, then most of the fish emerge through the lateral faces of the trawl.

Table 7 shows the emergence of the rock grenadier through the mesh of the front part of the trawl when trawling along an isobath around the top of banks.

Table 8 presents the findings on the emergence of rock grenadier through the mesh of the belly in trawling along a slope of banks from top to bottom.

A relatively large number of rock grenadier emerges through the mesh of the netting, which is evidently due to the low rate of its movement. The rock grenadier does not hurry to move away from the approaching net webbing /129 and finds itself "sieved" through the large mesh of the net webbing and the cable elements. Emergence of rock grenadier through 100 and 60 mm netting mesh is scarcely observed.

It is obvious that a reduction in the emergence of the fish from the trawl, especially in the "critical zone" should be sought in order to improve the catching qualities of fishing gear.

TABLE 7

Emergence of rock grenadier through the mesh in the front part of the trawl

Type of trawl	Averaged mass of fish kept back by coverings, kg		
	upper face	lower face	side face
"Makrurus" ("Rock grenadier")	4	10	127
Experimental	3	44	75

TABLE 8

Emergence of rock grenadier through mesh of trawl belly

Trawl sheets	Lower	Side	Upper
Averaged mass of fish in one covering, kg	10.17	10.74	24.60

Requirements for trawl designs. The Middle-Atlantic Ridge is characterized by the presence of banks which consist of ocean floor elevations of small area that terminate in acutely pointed peaks. The angles of inclination of the slopes of the elevations are 11-14° on average, and up to 30° on some banks. As we have noted, rock grenadier accumulations are distributed abote the peak and along their slopes.

The use in these regions of trawls designed for catching traditional fish species leads to frequent tears of the lower and side sheets, and sometimes to the loss of the whole apparatus, including the cable connection. In most cases, the trawl cannot be repaired owing to the loss of the greater part of the net and cable webbing. Some ships are obliged to stop fishing after 10-20 days of work, having used up the available trawls, equipment and fishing gear parameter control devices. Based on data of work of commercial ships, each 20th haul of a midwater trawl meets with an accident, each fourth one

for a bottom trawl. /130

The existing trawl design contains catching, directing and retaining parts. The main purpose of the catching part is to increase the catching zone. In order to catch deep-water fish on submarine elevations, this part of the trawl must, in addition to its basic purpose, serve the function of increasing the maneuverability of the trawl complex, improving targeting at fish schools and preventing equipment accidents, that is, it must have high reliability.

The assortment of the net webbing and the dimensions of the trawl parts are determined on the basis of fish behavior.

These requirements are best satisfied by a trawl design with separately functioning sheets in the front part. On the basis of these requirements, the Special Design Office of the fisheries Industry has developed a deep-water trawl design prospectus 2214, which has been adopted as equipment in fisheries vessels.

CONCLUSION

Rock grenadier accumulations in the Middle-Atlantic Ridge region are usually situated over peaks and along the slopes of deep-water banks at depths of 500-1500 m. The frequency of occurrence of its schools situated in the catching zone, depending on their vertical development, horizontal extent and the distance btween schools, most often corresponds to log-normal and Maxwell distribution.

In catching rock grenaider, a large emergence (60-70% of the catch in the trawl belly) is observed through large-mesh netting. The peculiarities of the distribution and behavior of the rock grenadier in the catching zone must be taken into account in developing a more efficient trawl.